Claims

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1. A method of predicting the location of a CDMA mobile communications unit in a wireless communications service area, comprising the steps of:

(a) receiving measured attribute information from a mobile unit location in the service area, said attribute information being specific to the location of the mobile unit in the service area;

(b) computing the probability of the mobile unit being at a specific location in the service area in response to said received attribute information using a likelihood probability function;

(c) generating an output indicative of the likelihood of the mobile unit being at said location in the service area.

2. A method according to claim 1 wherein said likelihood probability function comprises an iterative procedure for producing a maximum likelihood estimator of the mobile unit's location in this service area.

3. A method according to claim 2 wherein the maximum likelihood estimator comprises the coordinates in the service area which maximizes the likelihood probability function.

4. A method according to claim 2 wherein said likelihood probability function comprises a frequentist likelihood function.

5. A method according to claim 2 wherein said likelihood probability function comprises a Bayes-modified likelihood function.

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6. A method according to claim 1 wherein said procedure comprises a sequential Bayesian type of procedure.

7. A method according to claim 6 wherein said sequential Bayesian type of procedure uses a frequentist likelihood function.

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8. A method according to claim 6 wherein said sequential Bayesian type of procedure uses a Bayes-modified likelihood function.

9. A method according to claim 1 and wherein said attribute information comprises a pilot signal strength measurement of at least one visible pilot signal at said location of the mobile unit.

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10. A method according to claim 9 and additionally including a step (d) prior to step (b) of reducing the effective size of the service area so as to reduce the number of computations required in step (b).

11. A method of claim 9 and following step (a) and before step (b), additionally including a step (d) of identifying a region A of support for the mobile unit in the service area and (e) identifying a set of possible pilot signals which can be detected by the mobile unit in said region of support.

12. A method of claim 11 and additionally including a step (f) of computing an approximation $\widetilde{\theta}_{ij}(x,y)$ of the probability the mobile unit detects a pilot signal at said specific location (x, y) in said region A for all pilot signals in said set of possible pilot signals and where j is a sector of a multi-sector base station i in said region of support.

13. A method of claim 12 wherein $\widetilde{\theta}_{ij}(x,y)$ is derived from an RF model for the RF power $R_{ij}(x,y)$ received by the mobile unit and where the model is of the form of

$$R_{ij}(x,y) = T_{ij}G_{ij}(x,y)L_{ij}(x,y)F_{ij}(x,y)M_{ij}(x,y)$$

where T_{ij} is the transmit power associated with the sector j of base station i, $G_{ij}(x,y)$ is the antenna gain for the sector j of base station i along the direction pointing towards the location (x, y) within A, $L_{ij}(x,y)$ is the distance loss between the base station i associated with the sector j and the location (x, y) within A, $F_{ij}(x,y)$ is the shadow fading factor and $M_{ij}(x,y)$ is the measurement noise factor.

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14. A method according to claim 13 wherein said attribute information comprises the measured visibility of a pilot signal transmitted from a base station and the likelihood probability function comprises an iterative freuentist maximum likelihood (ML) function in the form of

$$L^{s}_{ML}(x,y) \propto L^{s-1}_{ML}(x,y) \prod_{ij \in K} [\tilde{\theta}_{ij}(x,y)]^{\mu^{s}_{ij}} [1-\tilde{\theta}_{ij}(x,y)]^{1-\mu^{s}_{ij}} \quad , \quad (x,y) \in A$$

where x and y comprise rectilinear coordinates in the service area A, s is the number of measurement epochs, and μ^{s}_{ij} is equal to one or zero depending on whether the mobile unit can detect a pilot signal ij at measurement epoch s.

15. A method according to claim 13 wherein said attribute information comprises the measured visibility of a pilot signal transmitted from a base station and the likelihood probability function comprises an iterative Bayes-modified maximum likelihood (ML) estimator in the form of

$$L^{s}_{BML}(x,y) \propto L^{s-1}_{BML}(x,y) \prod_{ij \in K} \frac{[n^{s-1}_{ij} + \alpha_{ij}(x,y)]^{\mu^{s}_{ij}} [s-1-n^{s-1}_{ij} + \beta_{ij}(x,y)]^{1-\mu^{s}_{ij}}}{\alpha_{ij}(x,y) + \beta_{ij}(x,y) + s - 1} \quad , (x,y) \in A$$

where x and y comprise rectilinear coordinates in the service area A s is the number of measurement epochs, n^{s-1}_{ij} is the number of times a pilot signal in section j of a multi-sector base station i is visible through the first s-1 measurement epochs, $\alpha_{ij}(x,y)$ and $\beta_{ij}(x,y)$ are

parameters of a beta distribution, and μ_{ij}^{s} is equal to one or zero depending on whether the mobile unit can detect a pilot signal ij at measurement epoch s.

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16. A method according to claim 15 where

$$\alpha_{ij}(x,y)=\begin{cases} 1 & ,if\ \tilde{\theta}_{ij}(x,y)\le 1/2 \\ \dfrac{\tilde{\theta}_{ij}(x,y)}{1-\tilde{\theta}_{ij}(x,y)} & ,if\ \tilde{\theta}_{ij}(x,y)>1/2 \end{cases}$$

$$\beta_{ij}(x,y)=\begin{cases} \dfrac{1-\tilde{\theta}_{ij}(x,y)}{\tilde{\theta}_{ij}(x,y)} & ,if\ \tilde{\theta}_{ij}(x,y)\le 1/2 \\ 1 & ,if\ \tilde{\theta}_{ij}(x,y)>1/2\,. \end{cases}$$

17. A method according to claim 13 wherein the frequentist likelihood function $L_{ML}^{s}(x,y)$ is combined with a discrete uniform prior distribution for the location of the mobile unit of the form

$$P_{ML}^{o}(x,y)=\frac{1}{\|A\|},(x,y)\in A$$

to generate a sequential Bayesian procedure which provides a posterior distribution for the location of the mobile unit of the form

$$P_{ML}^{s}(x,y)\propto P_{ML}^{s-1}(x,y)\prod_{ij\in K}[\tilde{\theta}_{ij}(x,y)]^{\mu_{ij}^{s}}[1-\tilde{\theta}_{ij}(x,y)]^{1-\mu_{ij}^{s}}\ ,\ (x,y)\in A.$$

where $\|A\|$ is the number of grid points contained within A, and where x and y comprise rectilinear coordinates in the service area A, s is the number of measurement epochs, and

μ_{ij}^s.is equal to one or zero depending on whether the mobile unit can detect a pilot signal ij.at measurement epoch s.

18. A method according to claim 13 wherein the frequentist likelihood function $L_{BML}^s(x,y)$ is combined with a discrete uniform prior distribution for the location of the mobile unit of the form

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$$P_{BML}^9(x,y) = \frac{1}{\|A\|}, (x,y) \in A$$

to generate a sequential Bayesian procedure which provides a posterior distribution for the location of the mobile unit of the form

$$P_{BML}^s(x,y) \propto P_{BML}^{s-1}(x,y) \prod_{ij \in K} \frac{[n_{ij}^{s-1} + \alpha_{ij}(x,y)]^{\mu_{ij}^s} [s-1-n_{ij}^{s-1} + \beta_{ij}(x,y)]^{1-\mu_{ij}^s}}{\alpha_{ij}(x,y) + \beta_{ij}(x,y) + s - 1}, \ (x,y) \in A.$$

where $\|A\|$ is the number of grid points contained within A, and where x and y comprise rectilinear coordinates in the service area A, s is the number of measurement epochs, n is the number of times a pilot signal in section j of a multi-sector base station i is visible through the first s-1 measurement epochs, $\alpha_{ij}(x,y)$ and $\beta_{ij}(x,y)$ are parameters of a beta distribution, and μ_{ij}^s,is equal to one or zero depending on whether the mobile unit can detect a pilot signal ij at measurement epoch s.

19. A method according to claim 18 where

$$\alpha_{ij}(x,y) = \begin{cases} 1 & , if\ \tilde{\theta}_{ij}(x,y) \le 1/2 \\ \dfrac{\tilde{\theta}_{ij}(x,y)}{1-\tilde{\theta}_{ij}(x,y)} & , if\ \tilde{\theta}_{ij}(x,y) > 1/2 \end{cases}$$

$$\beta_{ij}(x,y) = \begin{cases} \dfrac{1-\tilde{\theta}_{ij}(x,y)}{\tilde{\theta}_{ij}(x,y)} & , if\ \tilde{\theta}_{ij}(x,y) \le 1/2 \\ 1 & , if\ \tilde{\theta}_{ij}(x,y) > 1/2. \end{cases}$$

20. Apparatus for estimating the location of a mobile communications unit in the service area of a wireless communications system comprising:

a plurality of base stations and at least one switching center providing a common access to said plurality of base stations;

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computing apparatus including a memory, electrically connected to at least one of said base stations or said switching center, for storing a set of parameters of a model of the wireless communications system including the RF environment and predicted values of attribute measurement of the service area and wherein the values of the parameters are adjusted to obtain a substantial match between measured attribute values at a predetermined number of locations in the service area and the corresponding initial values predicted by the model;

said computing apparatus further including software for calculating, in response to one or more attribute values being measured and reported by the mobile unit from a specific location within the service area, a predicted location of the mobile unit within the service area using a likelihood probability function; and,

circuit means coupled to said computing apparatus for generating an output indicative of the predicted location of the mobile unit.